Microbial Source Tracking Study

FINAL REPORT ON TASK 7 OF THE INTEGRATED WATER RESOURCES MANAGEMENT PROGRAM

TOWN OF COLCHESTER, VERMONT

Project ID 051694-G

January 3, 2012

This project is funded by a US EPA National Decentralized Wastewater Demonstration Grant (XP-83232201-1)

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EXECUTIVE SUMMARY

On several occasions over the past 15 years, pathogen levels in various surface water bodies in the Town of Colchester, Vermont have exceeded state water quality standards for contact recreation, such as swimming and wading. In 2001, the University of New Hampshire (UNH) conducted a study in Colchester using a process called ribotyping, where patterns of genetic material extracted from *E. coli* (fecal indicator bacteria) from water quality samples are matched with patterns from *E. coli* associated with known sources. The outcome of the ribotyping is a list of known and unknown sources from the sample and an estimate of their relative proportion in the sample. This study was designed to expand on Colchester's ongoing beach monitoring program and the 2001 ribotyping study.

During the summers of 2009 and 2010, the water quality sampling program at the town's beaches was augmented to include microbial source tracking for 13 sampling events. Selected samples, typically with elevated concentrations of *E. coli*, were processed at Endyne Laboratory in Williston, Vermont to prepare isolates, or individual colonies of *E. coli*. These were sent to UNH's Jackson Estuarine Laboratory in Durham, New Hampshire, for preservation and ribotyping in order to characterize the source species associated with the *E. coli* present in the samples.

To better locate the apparent sources of bacteria, water quality samples were collected from streams and creeks flowing into inner Malletts Bay in the summer and autumn of 2010. Additionally, samples of fecal matter from known sources were collected and analyzed to provide a local library of source ribotypes to supplement UNH's regional library.

The outcomes of the Microbial Source Tracking (MST) study are as follows

1. Sources of fecal indicator bacteria include wild birds, wild animals, pets, livestock, and humans.
2. Over the course of the study, 65% of fecal indicator bacteria sources were identified.
3. Wildlife are the predominant sources of fecal indicator bacteria in Colchester's beaches and streams
4. Domestic pets (dogs and cats) and livestock (cows and horses) each make up a very small proportion of the fecal indicator bacteria sources.
5. Fecal indicator bacteria originating directly from human activities comprised 8.5% of all identified sources.
6. Evidence of human sources was found in nine locations. These human sources can have a range of origins, including, but not limited to: malfunctioning septic systems, overboard discharges from boats, trash/garbage, and swimming/wading. The locations where human sources of bacteria were identified include:
    a. Beaches
        i. Rossetti Beach

ii. Moorings Stream Box Culvert

iii. Bayside Beach

iv. 60 East Lakeshore Drive

v. Smith Hollow Beach

b. Stream Watersheds

i. Smith Hollow Creek

ii. Crooked Creek

7. Overall, wildlife (birds and animals) appear to be the most abundant sources of fecal indicator bacteria in Colchester's surface waters; the combined contribution of domestic animals and pets, and the contribution of human sources, both appear to be relatively low. Therefore the majority of sources are due to factors that are not under the control of the Town of Colchester.
8. The water quality sampling sites were selected based on public health considerations. Therefore, the outcomes of the project were focused on the beaches and nearby tributaries.
9. Opportunities for managing the sources include additional ribotyping, field investigations, wildlife deterrents, and public education.

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1. INTRODUCTION

Stone Environmental, Inc. of Montpelier, Vermont and Stephen Jones, Ph.D., of the University of New Hampshire's Jackson Estuarine Laboratory, Durham, New Hampshire, were engaged by Aldrich + Elliott Engineers to conduct a Microbial Source Tracking (MST) program as part of the Town of Colchester, Vermont's Integrated Water Resources Management Project (IWRMP). The purpose of this task is to characterize sources of *E. coli* bacteria that occasionally exceed the Vermont water quality standard at Colchester's beaches and tributaries draining to Malletts Bay.

1.1. Bacteria in Surface Waters

Contact recreation (swimming, wading, fishing, etc.) in surface water that is contaminated with pathogens can result in gastrointestinal illness. *Escherichia coli* (*E.coli*) bacteria are used as an indicator of contamination originating from the fecal material of warm-blooded birds and mammals. *E. coli* are an indicator of the potential presence of disease-causing microorganisms, and are not necessarily themselves pathogenic. As such, monitoring levels in surface water provide a degree of public health protection. Results of laboratory analyses, however, are typically not available until the day after the sample was collected. Characterization of the sources (geographic and species) of *E. coli* can provide a basis for proactive management of sources to minimize the public health risk.

1.2. Bacteria Monitoring in Colchester

The Town of Colchester has been sampling *E. coli* at beaches for approximately 15 years. Over the years, there have been exceedences of bacteria water quality standards resulting in a need to post beaches to notify beachgoers of the potential public health risk.

1.3. Draft Bacteria TMDL

The Draft Statewide Bacteria Total Maximum Daily Load (TMDL) recently released by the Vermont Department of Environmental Conservation includes a TMDL for Direct Smaller Drainages to Inner Malletts Bay (VT DEC, 2011). Crooked Creek and Smith Hollow Creek watersheds are the Direct Smaller Drainages to Inner Malletts Bay in the Draft TMDL. The Draft TMDL is concentration based and requires a 97% reduction in *E. coli* concentrations to meet the State of Vermont's current Water Quality Standard (WQS) of 77 organisms per 100 milliliters (ml) for Class B waters, which is the category of waters sampled in Colchester for study. The Draft TMDL also includes the concentration reduction necessary to meet United States Environmental Protection Agency (EPA) water quality criteria for contact recreation of 235 organisms per 100 ml single sample result and 126 organisms per 100 ml geometric mean of concentrations over a season. According to the Draft TMDL, concentration reductions of 90% for single samples and 53% for geometric mean would meet EPA criteria. Colchester has objected to a number of elements in the draft TMDL, as documented in their formal response (Appendix C).

1.4. Field Study Rationale

A field study was designed to characterize the most likely sources of the fecal indicator bacteria that have been detected in creeks and Lake Champlain in Colchester, as well as to determine the approximate geographic location of the sources, so they can be eliminated, mitigated, or managed, as needed and as possible.

2. OBJECTIVES

The objective of the MST program is to expand upon the town's existing beach water quality monitoring program by characterizing the distribution of sources of *E. coli* exceedences in Colchester's beaches and streams. To achieve this goal, a local library of *E. coli* ribotype patterns was created and additional stream water quality samples were analyzed to determine the geographic distribution of source species contributing to documented exceedences of bacterial water quality standards.

For reference, the Task 7 description from the Town of Colchester's (2007) IWRMP grant application follows:

"Conduct a Microbial Source Tracking program using DNA Ribotyping to determine the sources of *E-coli* contamination in Malletts Bay and to assist in determining the best approach to managing water resources in this area. This task will complement the evaluations of existing infrastructure in Tasks 3 through 6. Along with data collected in Tasks 1 through 6, this task will help establish a baseline of data to measure the effectiveness of increased efforts in managing water resources.

a. Develop Water Quality Sampling Program—Develop a sampling program in consultation with Dr. Stephen Jones of the University of New Hampshire. Include protocols for sample collection and preservation. Determine necessary scope of testing and analysis to produce statistically significant results. Designate water quality sampling locations to maximize the effectiveness of the sampling program. Design host-specific fecal matter sampling program to enhance UNH's existing library of *E. coli* from local humans, wildlife, domestic birds and animals. Develop the necessary quality and assurance programs for data collection and management.

b. Modify Quality Assurance Project Plan (QAPP)—For this task, quality assurance practices will be developed and implemented. These practices will sufficiently produce quality data to adequately meet the project objectives, and will minimize data loss due to uncontrolled conditions and malfunctions, as outlined in EPA regulation 40 CFR 31.45. A QAPP was developed in 2005 for this project. This plan will be modified for the MST work proposed under this task. (Note: An updated QAPP was submitted and approved by EPA on 12/4/08).

c. Develop Benchmark Data—Integrate new data and testing results with previously collected microbial source tracking data, and surface water quality monitoring data from the Town's files. Establish a benchmark of comparison for future ongoing monitoring to measure the effectiveness of water quality improvement efforts.

d. Sample Collection—Collect water and fecal samples at designated sampling locations in accordance with established protocols and procedures.

e. Ribotyping Analysis—A local laboratory will isolate *E. coli* from samples and prepare samples for transport. Transport water quality samples with confirmed concentrations of *E. coli* to the University of New Hampshire. Ribotyping will be used in conjunction with a previously established DNA library, to identify the sources of *E. coli*.

f. Final Report—Produce a final report outlining the results of the analysis, the establishment of benchmark data for future measurement, and a protocol and plan for future monitoring efforts."

3. METHODS

Study methods are described here. Analytical methods are described in Appendix A (UNH, 2009) and Appendix B (UNH, 2011), Standard Operating Procedures at Stone Environmental and the University of New Hampshire Jackson Marine Laboratory, and the project's Quality Assurance Project Plan (QAPP).

3.1. Sampling Site Selection

Two seasons of MST sampling were conducted, in 2009 and 2010. The selection of 2010 upstream sampling sites was based on the distribution of source species that were identified by the 2009 sampling program as causing the bacteria exceedences at beaches and associated inland waters in Colchester.

3.1.1. 2009 Sampling

In late summer 2009, the Town of Colchester conducted initial sampling at fifteen sites to provide a preliminary assessment of apparent sources for the *E. coli* bacteria causing exceedences of water quality standards at beaches in Colchester and adjacent streams (Figure 1).

3.1.1.1. Beach Sampling

In 2009, samples were collected at twelve of the Town of Colchester's routine beach sampling locations (Figure 1):

1. Inner Mallets Bay
    a. Moorings Stream (local designation: M7-MS)
    b. Bayside Beach (West, Central, and East) (local designation: MB-1, MB-2 and MB-3)
    c. 60 East Lakeshore Drive (local designation: M9-CT)
    d. Smith Hollow Beach (local designation: M8-SH)
    e. Crooked Creek Beach (local designation: M11-CC)
2. Outer Mallets Bay and Lake Champlain
    a. Delta Park Beach (local designation: M1-DP)
    b. Porters Point (local designation: M4-PP)
    c. Rossetti Beach, local designation: West and East (MR1-ROS and MR2-ROS)
    d. Spaulding West Beach (local designation: M6-SW)

Beach sampling for MST purposes was conducted by Steffen Parker, water quality sampler for the Town of Colchester, using separate sample collection at approximately the same time and location as routine beach samples.

3.1.1.2. Stream Sampling

In conjunction with the Town of Colchester's 2009 beach sampling events, stream samples were collected at the following locations along inner Malletts Bay (Figure 1):

1. Near the mouth of Smith Hollow Creek (location designation: M8A-SH)

2. Near the mouth of Crooked Creek (location designation: M11A-CC)
3. Near the mouth of Malletts Creek (location designation: M12-MC)

These locations were selected based on their proximity to previous sampling events conducted in 2004 and 2005.

Steffen Parker conducted stream sampling concurrently with collection of beach samples and delivered samples to Endyne for analysis.

As described in Appendices A & B, after the local laboratory analyses of *E. coli* concentrations were completed, a determination was made whether a set of samples should be prepared for ribotyping analysis and shipped to UNH. The decisions were based on selecting exceedences of the 77 organisms/100 ml WQS. Some samples with *E. coli* concentrations less than 77 organisms/100 ml were selected to provide better distribution of sources based on location and *E. coli* concentrations.

3.1.1.3. Fecal Sampling

Fecal sampling of wild and domestic sources required identification of the source species and therefore a sampling program was developed in concert with Susan Morse of Keeping Track, Huntington, Vermont, and Stephen Jones, University of New Hampshire, Durham, NH.

Keeping Track provided training to staff from Stone Environmental, Inc. and Aldrich + Elliott. All fecal samples in the local library were collected in the Town of Colchester, with special emphasis on the beaches and watersheds of Malletts Bay.

3.1.2. 2010 Sampling

Three sampling programs were conducted in 2010: a continuation of the Town of Colchester's 2009 beach sampling program; stream sampling by Stone in conjunction with the synoptic phosphorus study (a separate task in the IWRMP); and targeted water quality sampling upstream of inner Malletts Bay (Figures 1 and 2).

3.1.2.1. Beach Sampling

Based on results from 2009 sampling, a reduced number of town beach sampling sites were included in the 2010 sampling program. Separate samples were collected at the following town beach sampling sites in 2010:

1. Porters Point (M4-PP)
2. Spaulding Beach West (M6-SW)
3. Smith Hollow Creek Beach (M8-SH)
4. 60 East Lakeshore Drive (M9-CT)
5. Crooked Creek Beach (M11-CC)
6. Bayside Beach Center (MB2)
7. Rossetti Beach West (MR1)
8. Rossetti Beach East (MR2)

Sampling at Porters Point and Rossetti Beach West samples was discontinued near the beginning of the 2010 sampling season to save on analytical costs and focus on the sites most likely to exceed the Water Quality Standard and yield *E. coli* for later analysis.

3.1.2.2. Stream Sampling

In 2010, the town collected ten samples at the following stream sampling sites:

1. Moorings Stream box culvert outlet (M7-MS)
2. Smith Hollow Creek Outlet (M8A-SH)
3. Crooked Creek Outlet (M11A-CC)
4. Mallets Creek Outlet (M12-MC)

Three additional sets of samples were collected as part of the synoptic phosphorus study (Figure 2, Appendix A, and Stone, 2011). Two of these phosphorus sampling locations overlapped with town sampling locations:

1. Smith Hollow Creek outlet: Phosphorus site "SC" = Town beach site: "M8A-SH"
2. Moorings Stream Box Culvert: Phosphorus site "MS" = Town beach site "M7-MS"

3.1.2.3. Targeted Water Quality Sampling

Stone conducted targeted water quality sampling to bracket potential source areas. These thirty-two sampling locations are designated with the letter WQ (Figure 2). Fecal sampling was conducted based on observation of animals on beaches or knowledge of the habitat of species along streams and in adjacent upland areas in Colchester.

3.2. Sample Collection

During 2009 and 2010, water quality and fecal matter samples were collected by the Town of Colchester and Stone and analyzed for *E.coli*.

3.2.1. Water Quality Samples

In 2009, beach and stream water quality samples were collected by Town staff on seven dates between August, 12th and September 2nd (Appendix A).

In 2010, the Town of Colchester conducted 10 beach sampling events (Appendix B). The Town collected samples during routine beach monitoring on a weekly basis between July 7 and July 19; and between August 2 and September 8. Breaks in the sampling schedule were due to a shortage of analytical materials at the local laboratory. A total of 106 samples were collected and analyzed for *E. coli* and 23 samples were shipped to UNH for further analysis.

Stream samples were collected at twelve locations as part of the synoptic phosphorus study, on each: May 24, 2010 (dry weather); August 3, 2010 (wet weather); and August 19, 2010 (dry weather) (Stone 2011), with the

exception that sample S-4 was inadvertently not collected on 8/3/10 (Appendix B). Of the thirty-five phosphorus study samples analyzed for *E. coli*, twelve samples were sent to UNH for further analysis.

Targeted water quality sampling occurred at thirty-two locations on three occasions: August 18, 2010; September 14, 2010; and October 26, 2010. A total of thirty-two water quality samples were analyzed by Endyne for *E. coli* (Appendix B). Nineteen of these samples were sent to UNH, of which nine samples were selected for ribotyping (Tables 9 – 12 and Appendix A).

3.2.2. Fecal Samples

In autumn of 2009, sampling personnel collected fecal matter from a septic system (Bayside Park), as well as dog, horse, goose, gull, and wild turkey droppings (Appendix A). These samples were carefully packed in ice and sent directly to UNH for processing and analysis.

On February 9, 2010 and September 1, 2010, personnel from Stone, UNH, Aldrich + Elliott, and Keeping Track collected wild animal fecal matter at Colchester Pond and various locations near streams in Colchester. On March 16, 2010, August, 18, 2010 and October 26, 2010, Brent Toth of Stone Environmental collected fecal matter, packed them in ice, and sent to UNH samples including: deer (4), goose (3); septage (3); sediment (3); muskrat (3); raccoon (3); coyote (3); dog (2); otter (2); grouse (2); avian (2); mink (1); red fox (1); duck (1) (Appendix B).

3.3. Field Reconnaissance

The intent of field reconnaissance was to look for potential sources of bacterial contamination in Smith Hollow Creek and Crooked Creek watersheds. The field reconnaissance, conducted by Stone in 2010, consisted of walking along reaches of the streams looking for surface discharges from onsite wastewater systems in close proximity to the stream. In most instances, the presumed locations of onsite wastewater system components were not close to the streams. No obviously failing systems were observed during the study, although some areas of historic potential malfunctions were identified and included in the 2010 water quality sampling by Stone.

3.4. Sanitary Survey

A sanitary survey of the Smith Hollow Creek and Crooked Creek watersheds was conducted in November 2011. A complete description of the methodology used and findings from the survey is provided in Appendix D. The sanitary survey was performed to supplement the results of the MST study by looking for apparent human sources of bacterial contamination, and to further evaluate water quality concerns raised in the Draft Statewide Bacteria TMDL for bacteria, which included Smith Hollow Creek and Crooked Creek.

3.5. Secondary Data Collection

3.5.1. Water Quality Data

The Town of Colchester water quality data was provided by Steffen Parker.

3.5.2. Precipitation Data

Precipitation data was obtained from a cooperating weather station (Weather Underground network station KVTCOLCH4) on Belaire Drive in Colchester.

3.5.3. Watershed Boundaries

Stone Environmental determined watershed boundaries for the water resources characterization aspect of this project (IWRMP Tasks 1 and 2) using LIDAR digital topography and field evaluation of stormwater flow direction.

4. RESULTS AND DISCUSSION

The findings of the field investigation provide a characterization of the distribution of source species of *E. coli* at Colchester beaches and streams. This section provides a summary of the results described in more details in Appendices A and B, which were prepared by Dr. Stephen Jones of the University of New Hampshire's Jackson Estuarine Laboratory. The results are organized by location, beginning with the outer Malletts Bay beaches, followed by the inner Mallets Bay beaches, and then the watersheds of the major tributaries to inner Mallets Bay. The data in this section of the report is based on analysis of both 2009 and 2010 water quality samples, with the ribotyped unknown isolates compared to known samples collected in 2009 and 2010.

Wild birds (Canada geese, wild turkeys, gulls, etc.) are the apparent predominant source of a majority of the bacteria in beaches, while wild animals (deer, raccoons, rabbits, foxes, etc.) tend to predominate in the inland areas.

Identified pollution sources represent the best matches between ribonucleic acid (RNA) band patterns from water samples and database patterns, with all of the source identifications from this study based on 90 to 100% matching. The approach has several limitations, including the occurrence of some sample patterns that match multiple, unrelated sources, which renders these patterns useless for pollution source tracking. These are therefore included in results among unidentified sources. Other water sample isolates with unidentified sources have unacceptable degrees of similarity to known sources and therefore their sources may be new or overlooked sources, or they may represent unique *E. coli* strains that are not included in the library. They may also be from non-fecal sources, including *E. coli* growing in stream sediments, beach sand, or other environmental settings that promote their persistence.

Human sources of *E. coli* in the local library include septic tank samples, marina pump out tank samples, stormwater runoff from a solid waste landfill, and wastewater treatment plant effluent. In the water, sources include fecal matter washed off of swimmers or waders, particularly infants in diapers, and overboard discharge from boats with toilet facilities. Indirect sources include malfunctioning septic systems and improper disposal of trash, including diapers. Which of these are the points of origin of human sources cannot be determined from ribotyping. Additional field reconnaissance to visually identify potential sources and practices is necessary to confirm the location-specific origin(s) of human sources of bacteria.

The ability to identify sources is limited by the sources available in local and regional libraries. However, many of the unidentified sources may also indicate sources of *E. coli* that are not directly from fecal matter. In recent years, many studies have been conducted showing conclusively that *E. coli* can survive and re-grow in a surprising number of settings in the environment (e.g., stream and lake sediments, beach wrack, soil, garbage, and submerged aquatic plants) These are commonly called "naturalized" communities of *E. coli* and are not considered to originate directly from the digestive systems of warm-blooded animals. Several local samples of sediment and beach wrack were collected during this study but no naturalized *E. coli* was confirmed from these samples.

4.1. Wet and Dry Weather Conditions

- Analytical results are broken out by wet and dry weather conditions. Dry weather generally represents base flow in streams from groundwater and wet weather stream flow is dominated by stormwater runoff.
- For the purpose of this study, dry weather conditions are represented by less than 0.5 inches of rain in the preceding 48 hours; and wet weather conditions are represented by greater than or equal to 0.5 inches of rain in the preceding 48 hours.
- The rainfall measurements were based on one weather station on Belaire Drive in Colchester (section 3.4.2). Depending on the geographic distribution of particular rainfall events, this station may or may not be representative of actual conditions in specific watersheds. For example, summer thunderstorm-related rainfall events may be very localized and occur in one watershed, but not at the weather station. Therefore wet and dry weather designations should be considered as estimated, not absolute conditions.
- Watersheds respond differently to rainfall events, and therefore rainfall response may be greater than or less than 48 hours for individual watersheds.
- Overall, the MST sampling was conducted on 28 dry weather days and 6 wet weather days. Due to the wide range in *E. coli* concentrations, from single digits to thousands of organisms per 100 ml, geometric means are used to calculate representative concentrations at each location (Table 1 and Table 2 below) under wet and dry weather conditions. The wet weather geometric mean at each station was generally more than double the geometric mean of the dry weather events for most of the beaches and the stream outlets.
- Among the *E. coli* concentrations measured during the 2010 MST sampling conducted by the Town, only two sites had a statistically significant difference between wet and dry weather conditions: Smith Hollow Beach and the beach at 60 East Lakeshore Drive. Both of these beaches had higher wet weather *E. coli* concentrations relative to dry weather *E. coli* concentrations.

Wet weather water quality is generally dominated by surface water flows and wash-off of materials from the ground surface. Dry weather conditions are generally representative of groundwater flow into the surface waters. The statistical analysis was conducted because most geometric means for wet weather conditions in 2010 were approximately 2 to 8 times greater than dry weather geometric means for beaches (Table 1) and streams (Table 2). The exceptions to this trend were Bayside, Rossetti, Spaulding West, and Porters Point beaches, where samples collected during dry weather flows had similar or higher geometric means than samples collected during wet weather flows. To test the hypothesis that 2010 dry weather *E. coli* concentrations were statistically different from 2010 wet weather *E. coli* concentrations, a statistical analysis using Student's T-test was conducted, assuming a two-tailed distribution with unequal variance on the concentrations' normal and log-normal distribution. The results showed that only Smith Hollow Beach and 60 East Lakeshore Drive beach were statistically different at a 95% confidence level. However, the smaller number of wet weather sampling events relative to the number of dry weather sampling events may have

skewed the results of this analysis. Therefore, we were not able to clearly differentiate between wet weather and dry weather conditions over all sites. Statistical analysis of wet and dry weather concentrations over at least five years of town beach sampling data is recommended to better determine whether there is a statistically significant difference between wet weather and dry weather *E. coli* concentrations at these sites.

Table 1: Beach E. coli Sampling Data, 2009 and 2010

Date	Precipitation past 48 hours (inches)	Wet/Dry	MR2 (Rossetti Beach)	M6 (Spaulding West Beach)	MB2 (Bayside Beach)	M8 (Near Smith Hollow Creek)	M9 (Near Camp Tee)	M11 (Near Crooked Creek)
8/12/2009	0.00	Dry			112	6	131	75
8/17/2009	0.00	Dry	5	14	4	6	2	54
8/19/2009	0.00	Dry	< 2	< 2	12	8	8	42
8/24/2009	0.00	Dry	< 2	8	28	10	3	12
8/26/2009	0.15	Dry	6	12	4	4	15	52
8/31/2009	0.50	Wet	630	790	7	530	93	72
9/2/2009	0.00	Dry	5	2	13	11	5	6
7/7/2010	0.00	Dry	5	2	37	47	12	50
7/12/2010	1.28	Wet	8	3	40	127	63	112
7/19/2010	0.02	Dry	7	< 1	23	72	3	40
8/2/2010	0.00	Dry	< 1	< 1	43	95	51	41
8/9/2010	0.16	Dry	11	82	30	15	26	110
8/18/2010	0.04	Dry	39	21	75	18	3	200
8/23/2010	0.87	Wet	2	3	34	120	68	580
8/30/2010	0.00	Dry	6	3	6	105	5	32
9/1/2010	0.00	Dry	4	>1000	11	45	6	17
9/8/2010	0.14	Dry	20	22	>400	135	6	86
Geometric Means (Wet Weather)			22	19	21	201	74	167
Geometric Means (Dry Weather)			8	9	19	22	9	42

Notes: 1. If the 48 hour period preceding sampling contained rain events totaling 0.50 inches or more (those likely to produce runoff), it was classified as a "wet" weather sampling event, those with less than 0.50 inches of precipitation were classified as "dry" events.

2. Wet weather results shaded in blue, the remaining results are dry weather.

Table 2: Stream E. coli Sampling Data, 2009 and 2010

Date	Precipitation past 48 hours (inches)	Wet/Dry	M7 (Moorings Stream)	M8A (Smith Hollow Creek)	M11A (Crooked Creek)	M12 (Malletts Creek)
8/12/2009	0.00	Dry	135	200	393	
8/17/2009	0.00	Dry	2	250	190	42
8/19/2009	0.00	Dry	2	310	260	30
8/24/2009	0.00	Dry	2	880	340	34
8/26/2009	0.15	Dry	160	350	230	28
8/31/2009	0.50	Wet	22	250	160	62
9/2/2009	0.00	Dry	2	210	72	37
5/24/2010	0.00	Dry	63	45		42
7/7/2010	0.00	Dry	18	240	700	27
7/12/2010	1.28	Wet	28	243	990	62
7/19/2010	0.02	Dry	24	220	870	31
8/2/2010	0.00	Dry	7	290	530	34
8/3/2010	0.70	Wet	850	620		1000
8/9/2010	0.16	Dry	400	475	2000	33
8/18/2010	0.04	Dry	10	170	440	22
8/19/2010	0.02	Dry	13	150		40
8/23/2010	0.87	Wet	1300	2000	2000	120
8/30/2010	0.00	Dry	115	2000	400	46
9/1/2010	0.00	Dry	18	28	490	39
9/8/2010	0.14	Dry	32	280	1000	56
Geometric Means (Wet weather)			162	524	682	147
Geometric Means (Dry weather)			19	241	424	35

Notes: 1. If the 48 hour period preceding sampling contained rain events totaling 0.50 inches or more (those likely to produce runoff), it was classified as a "wet" weather sampling event, those with less than 0.50 inches of precipitation were classified as "dry" events.

2. Wet weather results shaded in blue, the remaining results are dry weather.

4.2. Beach Analyses

- Geometric means of *E. coli* concentrations for beaches under wet weather and dry weather conditions reveal that Smith Hollow Creek, Crooked Creek, and the Beach near 60 East Lakeshore Drive (near what is locally referred to as “Camp Tee”) appear to be generally higher under wet weather conditions than dry weather conditions (Table 1)

4.2.1. Outer Mallets Bay and Lake Champlain Beaches

The following beaches were sampled in outer Mallets Bay and along Lake Champlain outside of Mallets Bay (Figure 3):

1. Delta Park Beach
2. Porters Point
3. Rossetti Beach (R1= West and R2=East)
4. Spaulding West Beach

Table 3. Ribotyping Result Summary for Outer Mallets Bay Beaches (Rossetti & Spaulding West)

Date	Site	*E. coli* (cfu/100 ml)	Total Isolates	% ID'd	Wild Birds	Wild Animals	Domestic Animals	Human
8/31/09	MR1-ROS	550	5	80	Goose	Deer, Fox		Human
8/31/09	MR2-ROS	630	5	60		Fox, Coyote		Human
8/18/10	MR2-ROS	39	5	20	Goose			
9/8/10	MR2-ROS	20	5	40	Goose	Coyote		
8/31/09	M6-SW	790	4	25		Raccoon		
8/9/10	M6-SW	51	5	100	Turkey, Gull, Mixed	Fox	Dog	
9/1/10	M6-SW	>1000	5	20	Goose	Deer, Otter		

Notes: 1. Data sources: UNH 2010 and 2011 (Appendix A & B)

2. Wet weather results shaded in blue, the remaining results are dry weather.

Discussion of ribotyping results for Outer Malletts Bay Beaches:

- During the 2009 ribotyping sampling events, water quality standards were not exceeded at either Delta Park Beach or Porters Point, therefore no samples were processed and shipped to UNH for ribotyping from these locations. In 2010, Delta Park Beach and Porters Point Beach samples were not analyzed for ribotyping.
- At Rossetti Beach and Spaulding West Breach, the most commonly identified sources of *E. coli* appear to be wild animals, followed closely by wild birds
- Two incidences of human sources were detected at Rossetti Beach under wet weather conditions, out of 20 isolates analyzed for this location.
- No human sources were detected at Spaulding West Beach.
- Out of 20 isolates analyzed from samples collected at Rossetti Beach: 10 were unidentified, 8 were from wild birds and animals, and 2 were from human sources.

- Out of 14 isolates analyzed from samples at Spaulding West Beach: 7 were unidentified, 6 were from wild birds and animals, 1 was from a domestic animal (dog), and none were from human sources.

4.2.2. Inner Mallets Bay Beaches

The following beaches were sampled in inner Mallets Bay (Figure 4):

- Moorings Stream
- Bayside Beach (West, Central, and East)
- 60 East Lakeshore Drive
- Smith Hollow Beach
- Crooked Creek Beach

4.2.2.1. Moorings Stream Box Culvert

In 2009 and 2010, 20 water quality samples were collected in the Moorings Stream Box Culvert for the MST study. Of these samples, 6 exceeded the WQS for *E. coli*. Fifteen isolates from 4 samples were ribotyped (Table 4).

Table 4. Moorings Stream Culvert (M7-MS)

Date	Site	*E. coli* (cfu/100 ml)	Total Isolates	% ID'd	Wild Birds	Wild Animals	Domestic Animals	Human
8/12/09	M7-MS	135	2	50	Turkey			
8/26/09	M7-MS	160	5	20				Human
8/3/10	MS	850	3	67	Goose, Gull			
8/23/10	M7-MS	1300	5	100	Goose, Gull (2), Mixed Bird	Deer		

Notes: 1. Data sources: UNH 2010 and 2011 (Appendix A & B)
2. Wet Weather results shaded in blue, the remaining results are dry weather.
3. Site MS is in the same location as M7-MS.

Discussion of Moorings Stream sample results:

- In Moorings Stream (M7), the predominant identified sources of *E. coli* appear to be wild birds.
- One incidence of a human source was detected under dry weather conditions.
- Of the 15 isolates analyzed from samples collected at Moorings Stream outfall: 6 were unidentified, 8 were from wild birds and animals, none were from domestic animals, and 1 was from a human source.
- See section 4.3.1 (Table 9) for results of MST analyses of upstream sources.

4.2.2.2. Bayside Beach (Central)

In 2009 and 2010, 17 water quality samples were collected in Bayside Beach for the MST study. Of these samples, 2 exceeded the WQS for *E. coli*. Eighteen isolates from 4 samples were ribotyped (Table 5).

Table 5. Ribotyping Result Summary for Bayside Beach

Date	Site	*E. coli* (cfu/100 ml)	Total Isolates	% ID'd	Wild Birds	Wild Animals	Domestic Animals	Human
8/12/09	MB2-Bay	112	3	67	Goose	Fox		
8/18/10	MB2-Bay	75	5	100	Goose, Turkey	Fox, Deer		Human
8/23/10	MB2-Bay	34	5	60	Turkey	Deer(2)		
9/8/10	MB2-Bay	>400	6	100	Goose	Deer (3) Fox	Dog	

Notes: 1. Data sources: UNH 2010 and 2011 (Appendix A & B)
2. Wet Weather results shaded in blue, the remaining results are dry weather.

Discussion of ribotyping results for Bayside Beach:

- In the center sampling location on Bayside Beach (MB-2) the predominant source of *E. coli* are wild animals, chiefly deer, with significant contributions of wild birds (geese and turkeys) detected in two sampling events (Table 5)
- One incidence of a human source was detected under dry weather conditions.
- Out of 19 isolates analyzed, from samples at Bayside Beach: 3 were unidentified, 14 were from wild birds and animals, 1 was from a domestic animal (dog), and 1 was from a human source.

4.2.2.3. 60 East Lakeshore Drive

In 2009 and 2010, 17 water quality samples were collected at 60 East Lakeshore Drive (near Camp Tee) for the MST study. Of these samples, 2 exceeded the WQS for *E. coli*. Thirteen isolates from 3 samples were ribotyped (Table 6).

Table 6. Summary of Ribotyping for 60 East Lakeshore Drive (M9)

Date	Site	*E. coli* cfu/100 ml)	Total Isolates	% ID'd	Wild Birds	Wild Animals	Domestic Animals	Human
7/12/10	M9	63	5	40		Raccoon, Deer		
8/2/10	M9	51	4	100	Goose (2), Gull	Rabbit		
8/23/10	M9	68	4	50	Goose			Human

Notes: 1. Data sources: UNH 2010 and 2011 (Appendix A & B)
2. Wet Weather results shaded in blue, the remaining results are dry weather.

Discussion of ribotyping results for 60 East Lakeshore Drive:

- At 60 East Lakeshore Drive (M9)), the predominant identified sources of *E. coli* appear to be wild birds, followed in abundance by wild animals, equivalent to 92 % of the total number of isolates analyzed for this location.
- One incidence of a human source was detected under wet weather conditions.
- Out of 13 isolates analyzed from samples at 60 East Lakeshore Drive: 5 were unidentified, 7 were from wild birds and animals, none were from domestic animals, and 1 was from a human source.

4.2.2.4. Smith Hollow Beach

In 2009 and 2010, 17 water quality samples were collected at Smith Hollow Beach for the MST study. Of these samples, 5 exceeded the WQS for *E. coli*. Sixteen isolates from 4 samples were ribotyped (Table 7).

Table 7. Smith Hollow Beach Site SH

Date	Site	*E. coli* (cfu/100 ml)	Total Isolates	% ID'd	Wild Birds	Wild Animals	Domestic Animals	Humans
8/31/2009	M8-SH	530	5	40			Dog	Human
7/12/2010	M8-SH	127	5	40		Deer		Human
8/18/2010	M8-SH	18	3	67	Goose Turkey			
8/23/2010	M8-SH	120	3	100	Goose		Horse, Dog	

Notes: 1. Data sources: UNH 2010 and 2011 (Appendix A & B)
2. Wet Weather results shaded in blue, the remaining results are dry weather.

Discussion of Smith Hollow Beach:

- The identified sources of *E. coli* appear to be roughly balanced between wild birds and domestic animals/pets (horse and dog).
- Two incidences of a human source were detected under wet weather conditions.
- Out of 16 isolates analyzed, from samples at Smith Hollow Beach: 7 were unidentified, 4 were from wild birds and animals, 3 were from domestic animals, and 2 were from human sources.
- See section 4.3.2 (Table 10) for stream MST analyses in Smith Hollow Creek.

4.2.2.5. Crooked Creek Beach

In 2009 and 2010, 17 water quality samples were collected from Crooked Creek Beach for the MST study. Of these samples, 4 exceeded the WQS for *E. coli*. Twenty-four isolates from 5 samples were ribotyped (Table 8).

Table 8. Crooked Creek Beach Site M11-CC

Date	Site	*E. coli* (cfu/100 ml)	Total Isolates	% ID'd	Wild Birds	Wild Animals	Domestic Animals	Humans
8/12/09	M11-CC	75	5	100	Goose (3) Gull	Deer		
8/31/09	M11-CC	72	5	100	Turkey	Deer (3), Fox		
7/12/10	M11-CC	112	5	60	Goose (2)	Deer		
8/18/10	M11-CC	200	5	100	Goose, Mixed	Rabbit, Raccoon, Mixed		
8/23/10	M11-CC	580	4	75		Deer (2), Mixed		

Discussion of Crooked Creek Beach:

- The predominant identified sources of *E. coli* appear to be roughly balanced between wild animals and wild birds
- No incidences of human sources were detected.
- Of the 24 isolates analyzed: 3 were unidentified, 21 were from wild birds and animals, none were from domestic animals, and none were from human sources.
- See section 4.3.3 (Table 11) for results of MST analyses of upstream sources.

4.3. Stream Water Quality Data

In 2009, three stream outlet locations were sampled: Smith Hollow Creek, Crooked Creek, and Malletts Creek. In 2010, additional upstream locations were sampled in the watersheds of these three creeks and in Moorings Stream watershed to characterize the apparent sources of bacteria in streams that flow to inner Malletts Bay (Table 2).

Generally, stream outlets tended to have higher *E. coli* concentrations relative to beaches, and upstream streams tended to have more wild animal sources than wild bird sources.

4.3.1. Moorings Stream Watershed

In 2010, three water quality samples were collected in Moorings Stream watershed. One of these samples exceeded the WQS for *E. coli*. Three samples were selected for processing and shipping to UNH. One sample was ribotyped (Table 9).

Table 9. Ribotyping Result Summary for Moorings Stream

Date	Site	*E. coli* (cfu/100 ml)	Total Isolates	% ID'd	Wild Birds	Wild Animals	Domestic Animals	Human
10/26/10	WQ-48	12		NA*				
10/26/10	WQ-46	26		NA*				
10/26/10	WQ-47	238	5	60		Deer (3)		

Notes: 1. Data sources: UNH 2010 and 2011 (Appendix A & B)
2. Wet Weather results shaded in blue, the remaining results are dry weather.
* Available for Ribotyping per Appendix B Table 4 (UNH 2011 report)

Discussion of ribotyping results for Moorings Stream watershed:

- Multiple deer sources identified in one sample.
- Recommend ribotyping for additional samples: West Tributary (WQ-48) and East Tributary (WQ-46 & WQ-47).
- Of the 5 isolates analyzed: none were unidentified, 3 were from wild birds, none were from wild or domestic animals, and none were from human sources.
- MST results for Moorings Stream Box Culvert outlet are presented in section 4.2.2.1

4.3.2. Smith Hollow Creek Watershed

In 2009 and 2010, 29 water quality samples were collected in the Smith Hollow Creek Watershed for the MST study. Of these samples, 22 exceeded the WQS for *E. coli*. Forty isolates from 15 samples were ribotyped (Figure 5, Table 10).

Table 10. Ribotyping Result Summary for Smith Hollow Creek (from downstream to upstream)

Date	Site	*E. coli* (cfu/100 ml)	Total Isolates	% ID'd	Wild Birds	Wild Animals	Domestic Animals	Humans
9/14/10	WQ21*	40						
8/12/09	M8A-SH	243	5	60	Goose	Deer		Human
8/24/09	M8A-SH	880	5	100	Gull(2), Turkey	Muskrat	Dog	
8/31/09	M8A-SH	250	5	100	Goose, Mixed	Deer	Dog	Human
7/12/10	M8A-SH	243	5	60	Goose	Raccoon, Rabbit		
8/3/10	SC	620	5	80		Raccoon, Rabbit, Mixed		Human
8/18/10	M8A-SH	170	1	0				
8/19/10	SC	150	5	100	Goose, Turkey		Dog	Human (2)
8/23/10	M8A-SH	>2000	4	75	Goose (2)		Dog	
9/14/10	WQ20*	36						
10/26/10	WQ40*	29						
10/26/10	WQ42*	29						
9/14/10	WQ22*	84						
10/26/10	WQ41*	27						
9/8/10	WQ25	360	5	60	Goose	Deer	Sheep	

Notes: 1. Data sources: UNH 2010 and 2011 (Appendix A & B)
2. Wet Weather results shaded in blue, the remaining results are dry weather.
3. Site SC is in the same location as M8A-SH.

* Available for Ribotyping per Appendix B Table 4 (UNH 2011 report)

Discussion of ribotyping results for Smith Hollow Creek watershed:

- The predominant identified sources of *E. coli* near the outlet of Smith Hollow Creek appear to be wild birds, followed closely in abundance by wild animals.
- Three incidences of dog sources were identified near the outlet, two under wet weather conditions and one under dry weather conditions
- Five incidences of human sources were detected under dry (4) and wet (1) weather conditions near the outlet of Smith Hollow Creek.

- Of the 40 isolates analyzed: 9 were unidentified, 21 were from wild birds and animals, 5 were from domestic animals, and 5 were from human sources. MST results for Smith Hollow Beach are presented in section 4.2.2.4

4.3.3. Crooked Creek Watershed

In 2009 and 2010, 22 water quality samples were collected in the Crooked Creek watershed for the MST study. Of these samples, 19 exceeded the WQS for *E. coli*. Forty-three isolates from 11 samples were ribotyped (Figure 6, Table 11).

Table 11. Ribotyping Result Summary for Crooked Creek (from downstream to upstream)

Date	Site	*E. coli* (cfu/100 ml)	Total Isolates	% ID'd	Wild Birds	Wild Animals	Domestic Animals	Humans
8/12/09	M11A-CC	393	5	60	Goose, Turkey	Fox		
8/24/09	M11A-CC	340	5	20		Deer		
8/31/09	M11A-CC	155	5	40	Goose	Deer		
7/12/10	M11A-CC	990	2	50		Deer		
8/18/10	M11A-CC	440	5	100	Turkey, Pigeon	Otter (2)	Horse	
8/18/10	WQ05	210	5	100	Goose (3)	Deer		Human
8/23/10	M11A-CC	2000	5	40	Goose	Coyote		
10/26/10	WQ45*	18						
8/18/10	WQ06	104	3	100	Turkey	Rabbit		Human
8/18/10	WQ07	148	4	100	Goose	Deer	Dog	Human
8/18/10	WQ08	52	4	0				

Notes: 1. Data sources: UNH 2010 and 2011 (Appendix A & B)
2. Wet Weather results shaded in blue, the remaining results are dry weather.

* Available for Ribotyping per Appendix B Table 4 (UNH 2011 report)

Discussion of ribotyping results for Crooked Creek watershed:

- The predominant identified sources of *E. coli* appear to be wild birds, followed closely in abundance by wild animals.
- One incidence of a human source was detected near the outlet under wet weather conditions.
- Two incidences of human sources were detected upstream from the outlet under dry weather conditions.
- Of the 43 isolates analyzed: 17 were unidentified, 21 were from wild birds and animals, 2 were from domestic animals, and 3 were from human sources. MST results for Crooked Creek beach are presented in section 4.2.2.5.

4.3.4. Malletts Creek Watershed

In 2009 and 2010, 31 water quality samples were collected in Malletts Creek Watershed for the MST study. Of these samples, 16 exceeded the WQS for *E. coli*. Seventy-eight isolates from 16 samples were ribotyped (Figure 7, Table 12).

Table 12. Ribotyping Result Summary for Malletts Creek and Tributaries (from downstream to upstream)

Date	Site	*E. coli* (cfu/100 ml)	Total Isolates	% ID'd	Wild Birds	Wild Animals	Domestic Animals	Humans
8/24/09	M12-MC	34	5	60	Mixed	Muskrat, Raccoon		
7/12/10	M12-MC	62	5	60	Goose	Deer(2)		
8/23/10	M12-MC	120	5	40		Deer		Human
9/8/10	WQ32[I]	320	5	40		Raccoon, Fox		
10/26/10	WQ44[I]	91	5	60		Raccoon, Deer, Mixed		
8/3/10	PB[P]	390	5	100	Turkey (3)	Fox, Deer		
8/19/10	PB[P]	350	5	40	Goose (2)			
8/3/10	EH[P]	>1000	5	20	Goose			
8/19/10	EH[P]	590	7	86	Goose	Deer (5)		
8/3/10	VI[P]	88	5	40	Turkey	Deer		
8/19/10	VI[P]	830	5	60	Goose	Rabbit, Mixed		
10/26/10	WQ43[P]*	26						
8/3/10	MC	>1000	5	40	Goose	Raccoon		
8/19/10	MC	40	6	100	Goose(2), Gull(2), Mixed	Raccoon		
9/14/10	WQ31	500	5	20	Goose			
8/3/10	BH	680	5	60		Deer, Mixed	Dog	

Notes: 1. Data sources: UNH 2010 and 2011 (Appendix A & B)
2. Wet Weather results shaded in blue, the remaining results are dry weather.
3. Site MC is in the same location as M12-MC.
* Available for Ribotyping per Appendix B Table 4 (UNH 2011 report)
[I] Indian Brook Sub-watershed
[P] Pond Brook Sub-watershed

Discussion of ribotyping results for Malletts Creek watershed:

- The predominant identified sources of *E. coli* near the outlet of Malletts Creek appear to be wild animals, followed closely in abundance by wild birds.
- One incidence of dog sources was identified near the outlet under dry weather conditions

- One incidence of a human source was detected under dry weather conditions near the outlet of Malletts Creek.
- Out of 78 isolates analyzed, from samples at Malletts Creek watershed: 34 were unidentified, 43 were from wild birds and animals, 1 was from a domestic animal, and 1 was from a human source.

4.4. Watershed and Land Use Analysis

The total number of samples with ribotyped sources is too low to analyze statistically for each watershed individually. It is important to note however, that the majority of human *E. coli* sources were found in the two large stream watersheds with a concentration of residential development, Smith Hollow Creek and Crooked Creek. We know that:

- The *E. coli* concentration in samples from these streams was usually higher than the concentrations in samples from other streams or beaches.
- Human sources of *E. coli* were found more often in these watersheds, where there are a correspondingly large number of onsite wastewater treatment systems

Further field reconnaissance (a sanitary survey) was performed along both creeks to attempt to determine the apparent origin(s) of human sources of bacteria in these watersheds. The results of the sanitary survey can be found in Appendix D.

Land use is likely to influence concentrations of and sources of *E. coli* relative to dry weather and wet weather events. However, the sampling was focused on identifying potential sources of beach water quality impacts and the MST sampling program was not designed to compare the impact of land use on water quality. Groundwater generally provides the base flow in streams during dry weather conditions, and surface runoff tends to dominate stream flow during wet weather conditions. Based on analysis of 2010 results (section 4.1), only two beaches had statistically significant differences between dry and wet weather *E. coli* concentrations.

4.5. Summary of Findings

Approximately 65% of analyzed isolates were identified (Table 13). Wild birds and wild animals are the predominant source species, accounting for approximately half of all of the identified species.

The most predominant wild bird sources were Canada geese with 45 identified isolates overall (Tables 3-12). The predominant wild animal sources were white tailed deer with 41 identified isolates overall. The predominant domestic animal sources were dogs with 10 identified isolates overall.

Table 13. Ribotyping Result Summary for 2009 and 2010.

Sites Sampled	*E. coli* Samples Processed for Isolates	Total Number Isolates Analyzed	Number Isolates Identified	Total Wild Birds	Total Wild Animals	Total Domestic Animals	Total Humans
36	62	287	187	77	81	13	16

5. MANAGEMENT IMPLICATIONS OF FINDINGS

The management implications of these findings are quite significant and very timely. Wildlife (birds and animals) make up the majority of sources of bacteria in Colchester's surface waters and the contribution of domestic animals, pets, and human sources are relatively small. The majority of sources are therefore not under the control of the Town of Colchester.

As noted in the Draft Statewide Bacteria TMDL, Smith Hollow Creek and Crooked Creek have been included on the State of Vermont's list of impaired water bodies (derived from what is known as the 303(d) list which is based on criteria for impairment defined in the federal Clean Water Act §303(d)) (Appendix C).

Due to the detection of elevated concentrations of bacteria and human sources near the outlet of these creeks, sanitary surveys were conducted on Smith Hollow Creek and Crooked Creek in November 2011. The results of these sanitary surveys are included in a separate technical memo (Appendix D).

Potential management opportunities include:

- Wildlife sources
  - Construction of goose-deterring landscaping and complementary measures are recommended at town beaches, along with encouragement of similar voluntary measures at private beaches and bayside lawns. The State of Vermont Department of Fish and Wildlife notes that the following approaches to managing Canada Geese include: "harassment (e.g., horns, pyrotechnics, propane cannons), habitat management (e.g., vegetative barriers, longer grass management, fencing), cultural practices (e.g., crop selection and placement, management of pets and feeding schedules), or no feeding policies."
  - Continue water quality monitoring program to quantify long-term efficacy of goose deterrents.
- Pet sources
  - Increase pet waste removal stations and awareness program at town beaches and along sidewalks and paths in the Smith Hollow Creek and Crooked Creek watersheds.
- Human sources
  - Increase public education: encourage boat wastewater pump-out at marinas and report on the detrimental impact of overboard discharges on public health and water quality.

6. FIGURES

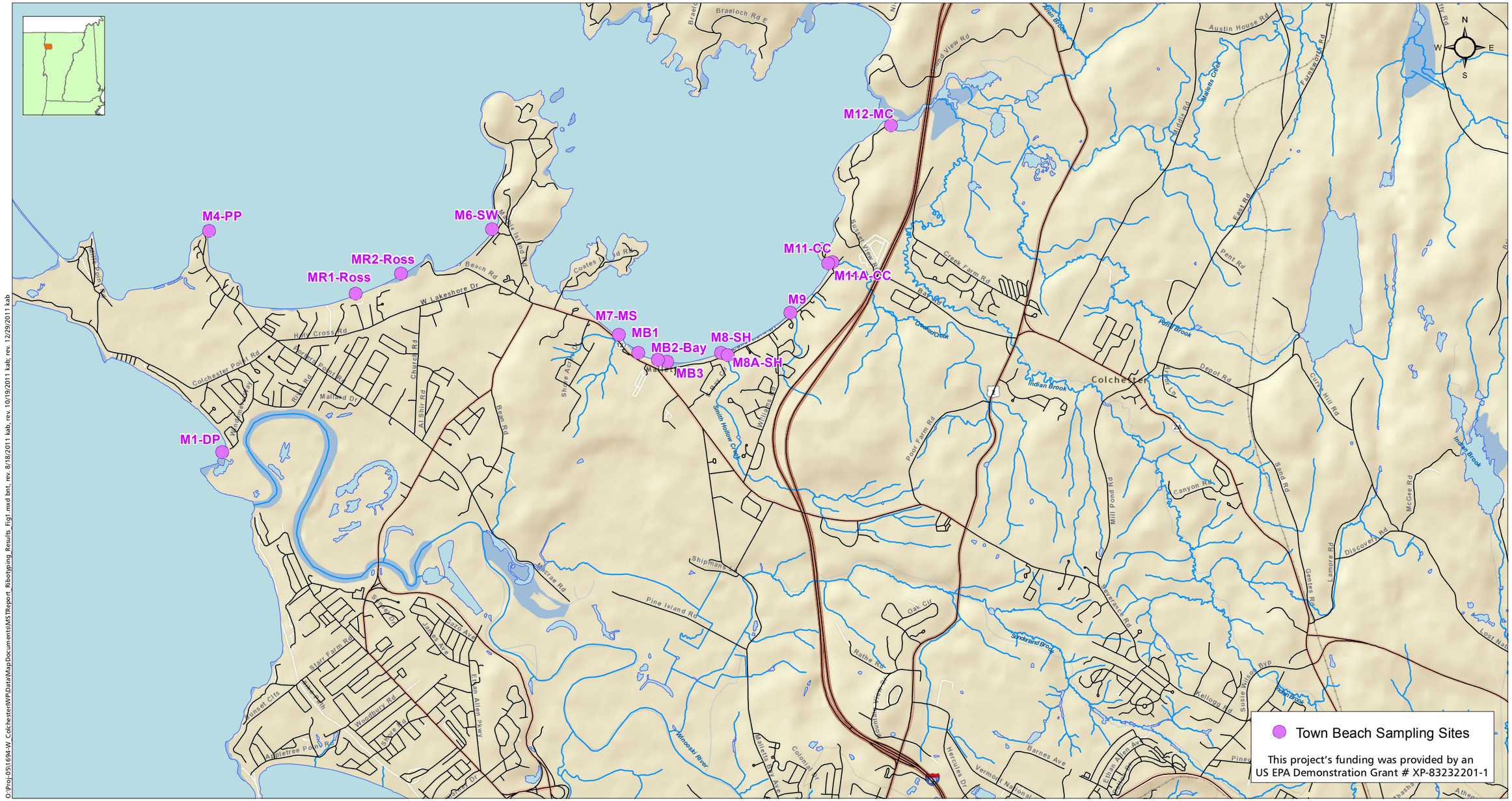

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Figure 1. Town of Colchester Beach Sampling Sites
Integrated Water Resources Management Program
Town of Colchester, Vermont

Sources: ESRI: Basemap, VCGI: Roads; Sampling Locations, Town of Colchester.

STONE ENVIRONMENTAL INC

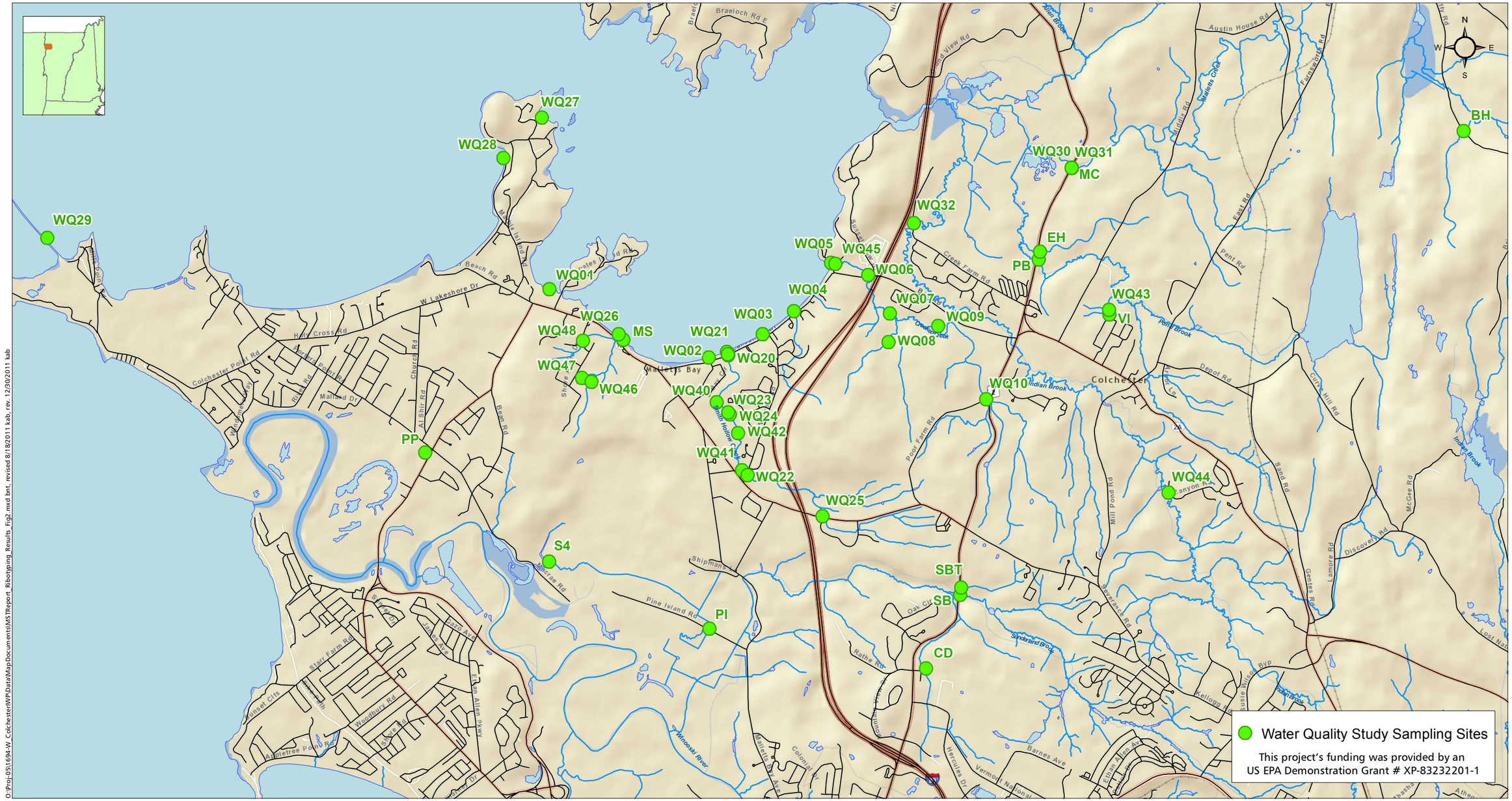

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Figure 2. Stone Environmental Water Quality Study Sampling Sites
Integrated Water Resources Management Program
Town of Colchester, Vermont

Sources: ESRI: Basemap, VCGI: Roads; Sampling Locations, Stone Environmental Inc.

STONE ENVIRONMENTAL INC

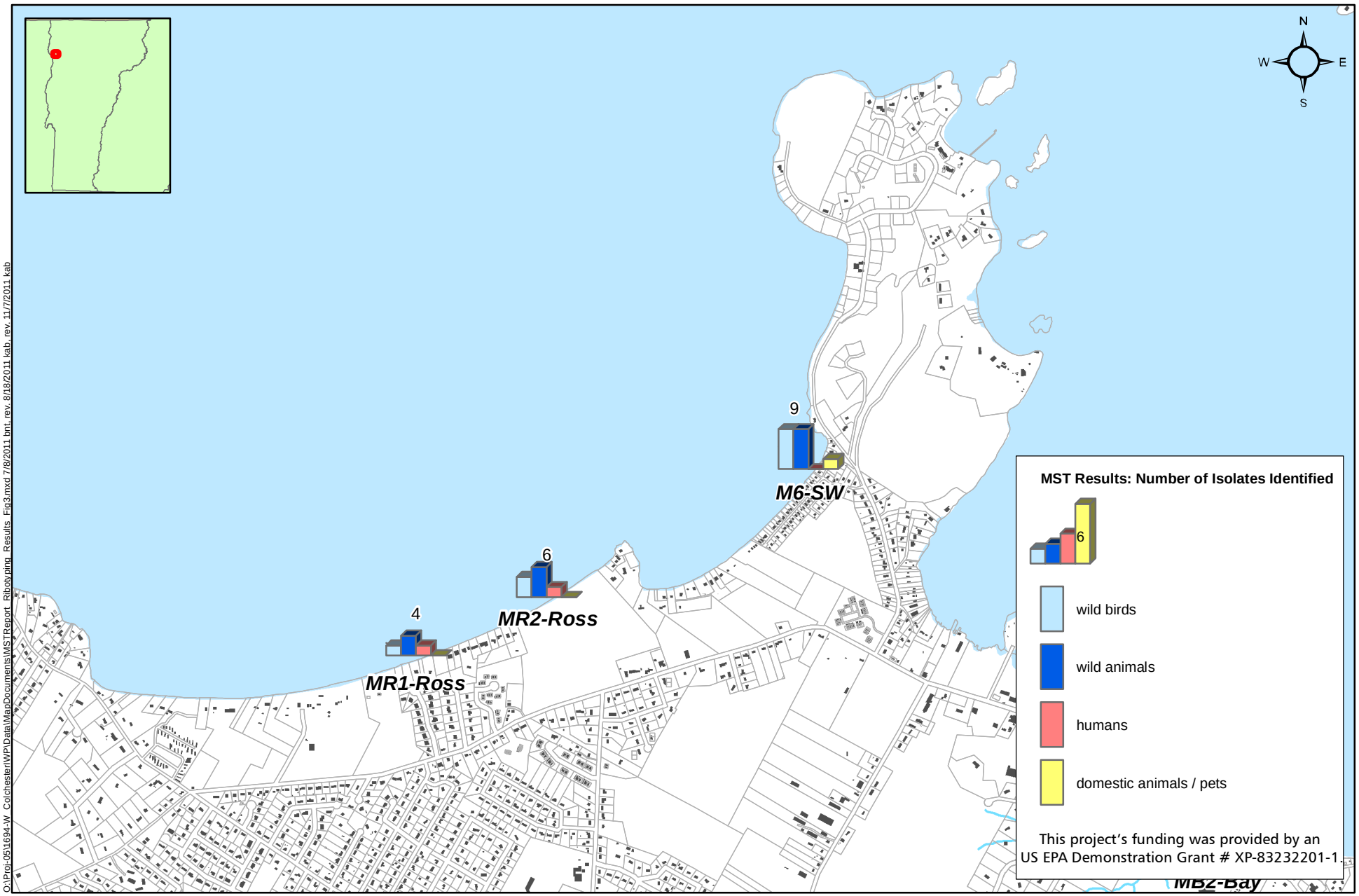

Figure 3. Outer Bay Beach Microbial Source Tracking (MST) Results

Integrated Water Resources Management Program
Town of Colchester, Vermont

0 0.25 0.5
Miles

Sources: VCGI: Streams, Water Bodies, Roads; Town of Colchester: Parcel Boundaries;
Stone Environmental, Inc.: Building Footprints; Stone Environmental Inc. and UNH: MST Sampling Results

STONE ENVIRONMENTAL INC

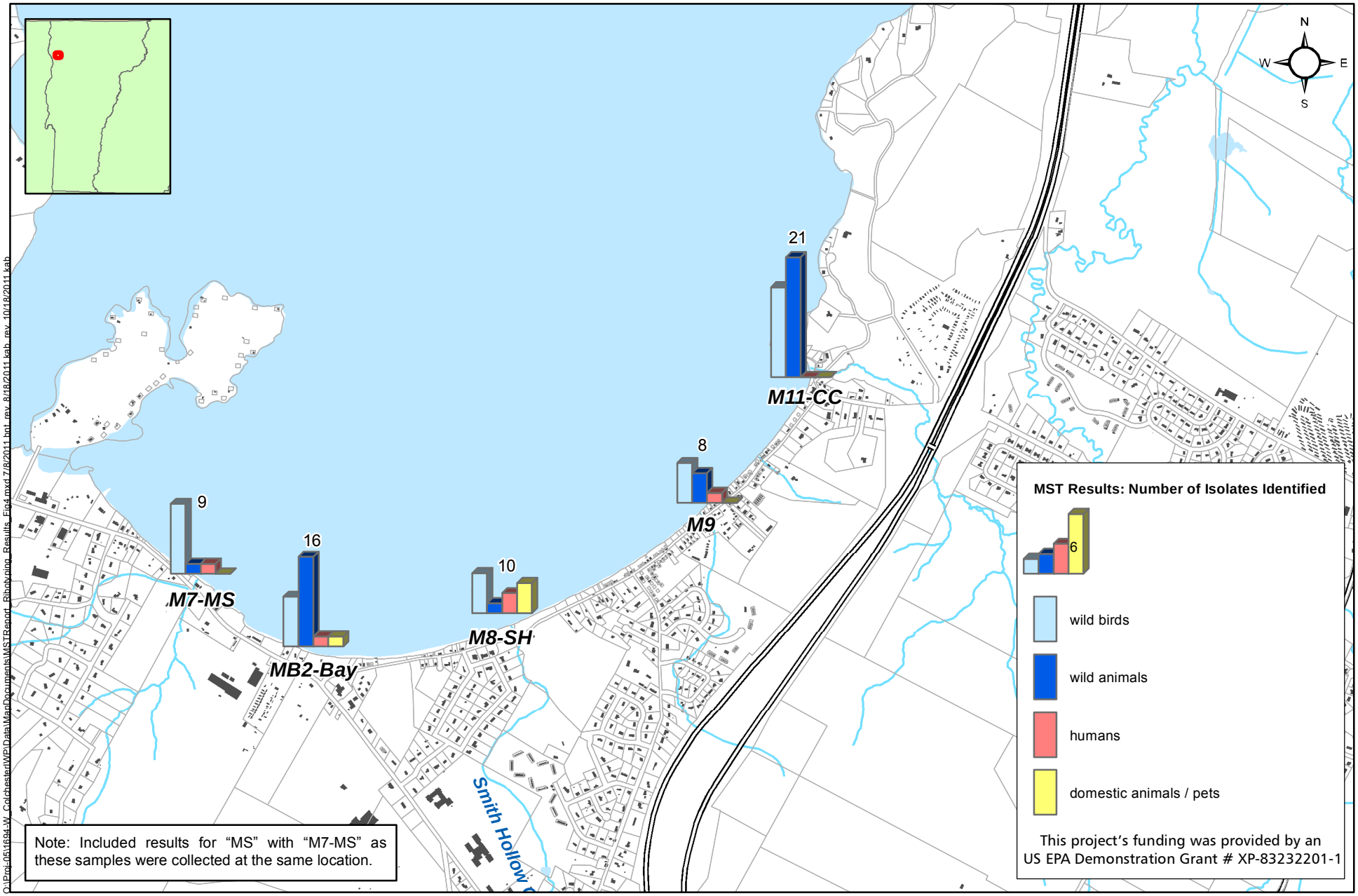

Figure 4. Inner Bay Beach Microbial Source Tracking (MST) Results

Integrated Water Resources Management Program
Town of Colchester, Vermont

Sources: VCGI: Streams, Water Bodies, Roads; Town of Colchester: Parcel Boundaries;
Stone Environmental, Inc.: Building Footprints; Stone Environmental Inc. and UNH: MST Sampling Results

STONE ENVIRONMENTAL INC

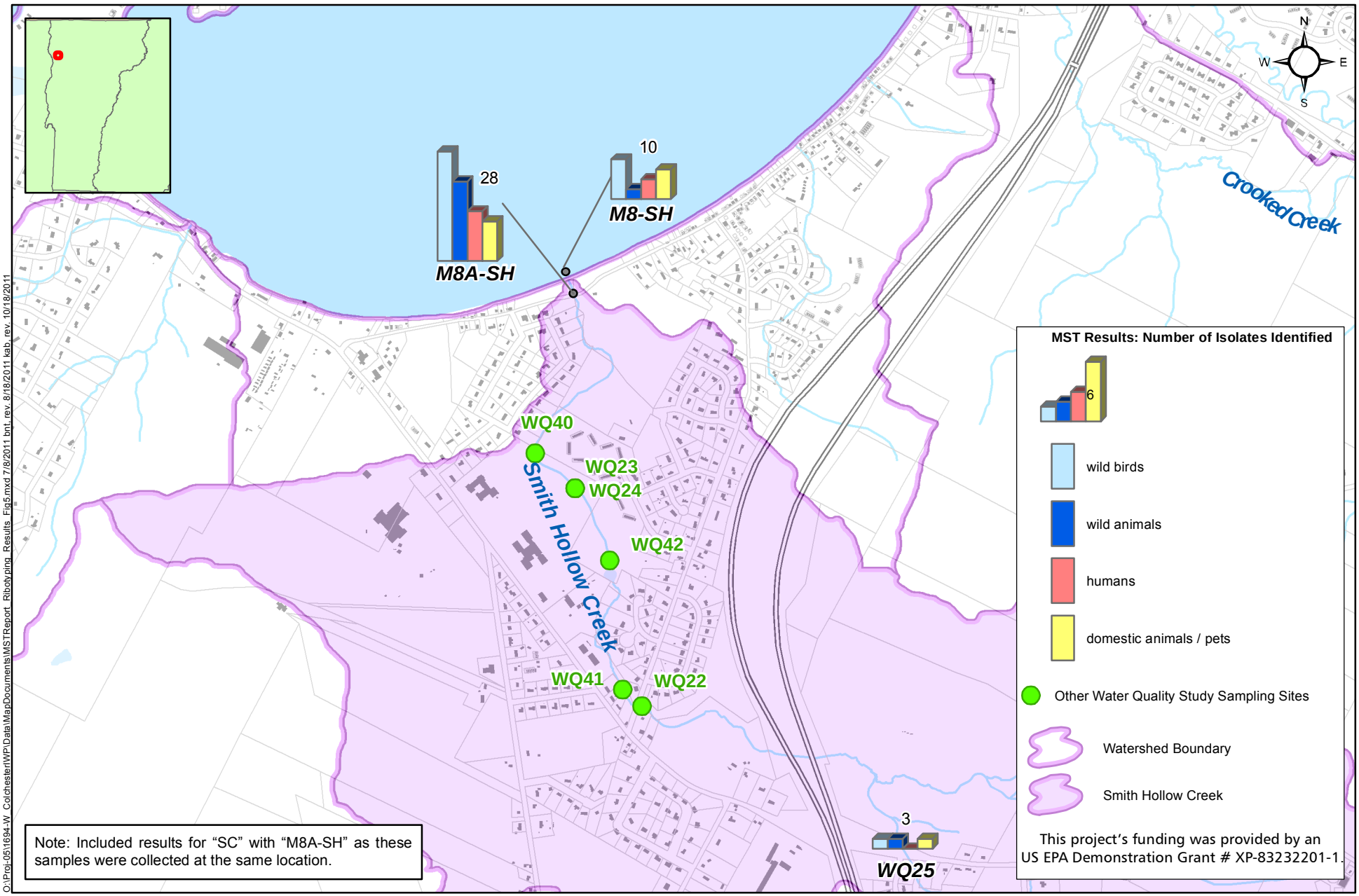

Figure 5. Smith Hollow Creek Watershed Microbial Source Tracking (MST) Results

Integrated Water Resources Management Program
Town of Colchester, Vermont

0 0.25 0.5
Miles

Sources: VCGI: Streams, Water Bodies, Roads; Town of Colchester: Parcel Boundaries;
Stone Environmental, Inc.: Building Footprints; Stone Environmental Inc. and UNH: MST Sampling Results

STONE ENVIRONMENTAL INC

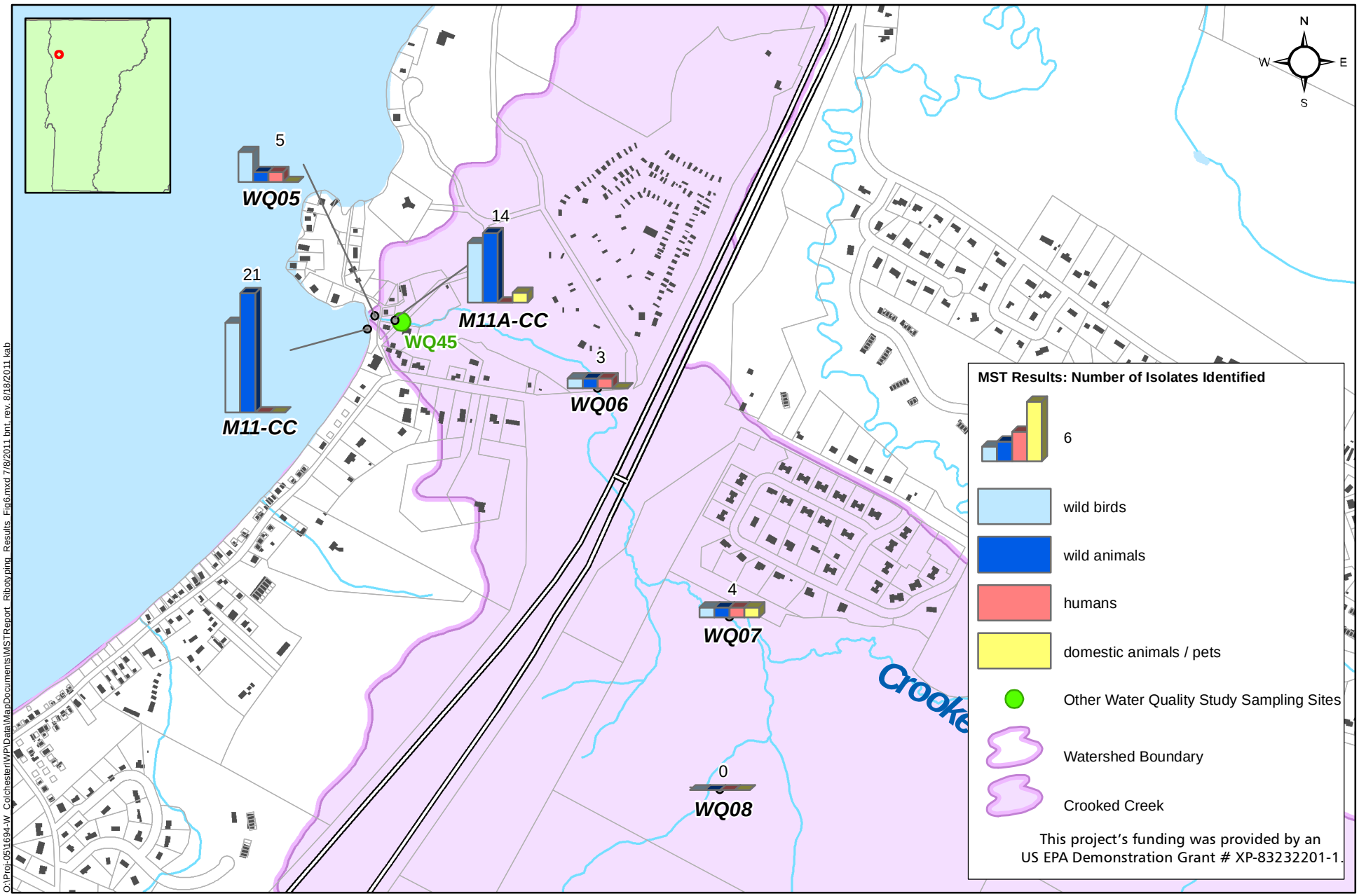

Figure 6. Crooked Creek Watershed Microbial Source Tracking (MST) Results

Integrated Water Resources Management Program
Town of Colchester, Vermont

0 0.125 0.25
Miles

Sources: VCGI: Streams, Water Bodies, Roads; Town of Colchester: Parcel Boundaries;
Stone Environmental, Inc.: Building Footprints; Stone Environmental Inc. and UNH: MST Sampling Results

STONE ENVIRONMENTAL INC

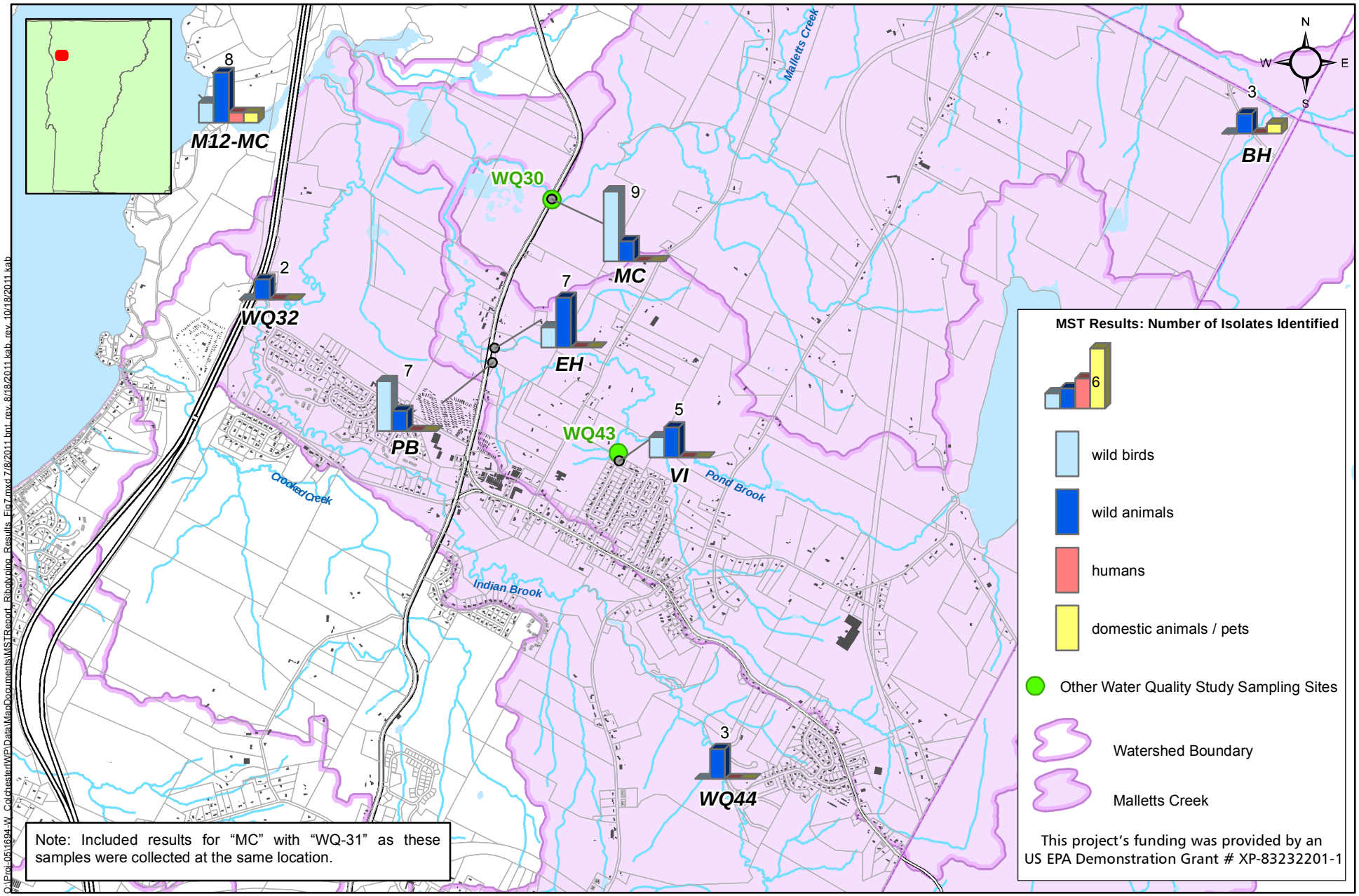

Figure 7. Malletts Creek Watershed Microbial Source Tracking (MST) Results

Integrated Water Resources Management Program
Town of Colchester, Vermont

0 0.25 0.5
Miles

Sources: VCGI: Streams, Water Bodies, Roads; Town of Colchester: Parcel Boundaries;
Stone Environmental, Inc.: Building Footprints; Stone Environmental Inc. and UNH: MST Sampling Results

STONE ENVIRONMENTAL INC